Identify the backbone structure of highway network system for Chinese 23 urban regions

Huiping Liu
Faculty of Geographical Science, Beijing Normal University, Beijing, 100875 China
hpliu@bnu.edu.cn

Xiangping Liu
School of Geosciences and Info-Physics, Central South University, Changsha,410083,China
Xpliu2018@csu.edu.cn

Lifu Zheng
Faculty of Geographical Science, Beijing Normal University, Beijing, 100875，China
201411181036@mail.bnu.edu.cn

Abstract

The structure of the transport network influences to a great deal the regional economic output. This paper tries to reveal backbone structure of 23 urban regions and its hidden influencing factors. The traffic volume between cities was crawled from Internet, and all-or-nothing assignment method used to allocate traffic volume to each road segment, thus extracting the backbone network of the transportation infrastructure. Based on the graph indexes as circuit and node degree, the spatial structure was identified into three different categories, which are linear structure, radial structure and network structure. From the geographical perspective, urban regions from the coastline are more tend to form a linear structure.

Keywords: structure of highway network, urban region, China, graph index, circuit, node degree

1 Introduction

The structure of the transport network influences to a great deal the regional economic output (Zhang, W., et al., 2017)). Transportation networks have an underlying structure, defined by the layout, arrangement and the connectivity of the individual network elements, namely the road segments and their intersections (Jiang B, 2009). The structure of networks shows a strong relationship with cities size and spatial interaction.

2 Study area and data

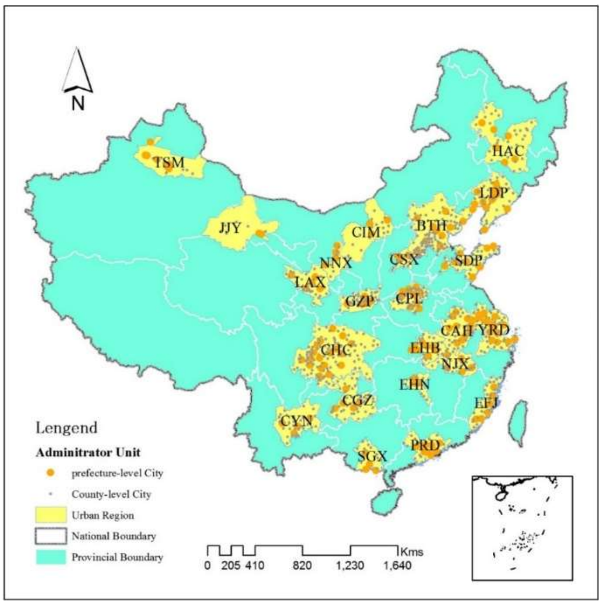
After a fast urbanization progress for last forty years, 23 urban regions have been identified across mainland by Fang(Fang, Song et al. 2010)(Fig.1).

In this paper, we obtained highway road shapefile from National Geomatics Center of China, with a composed classification of highways including expressway, national road, provincial road, county roads and urban street. The length of road segment was calculated on the ArcGIS platform, and the length was transformed into time cost based on the different grades of roads with different speed limit (Table 1).

The traffic volume offers the possibility of analyzing various features of the spatial organization of urban regions in a quantitative way. It reflects the spatial interaction strength between cities, as large amount of flux indicates strong interactions and vice versa. In China, nearly 90% traffic volume are highway passengers. So daily intercity bus schedules were download from bus.ctrip.com/ and checi.cn/ from data of January 11 to January 17 in 2018 spanning one week..

3 Methdology

Figure 1: The spatial extent of 23 urban regions



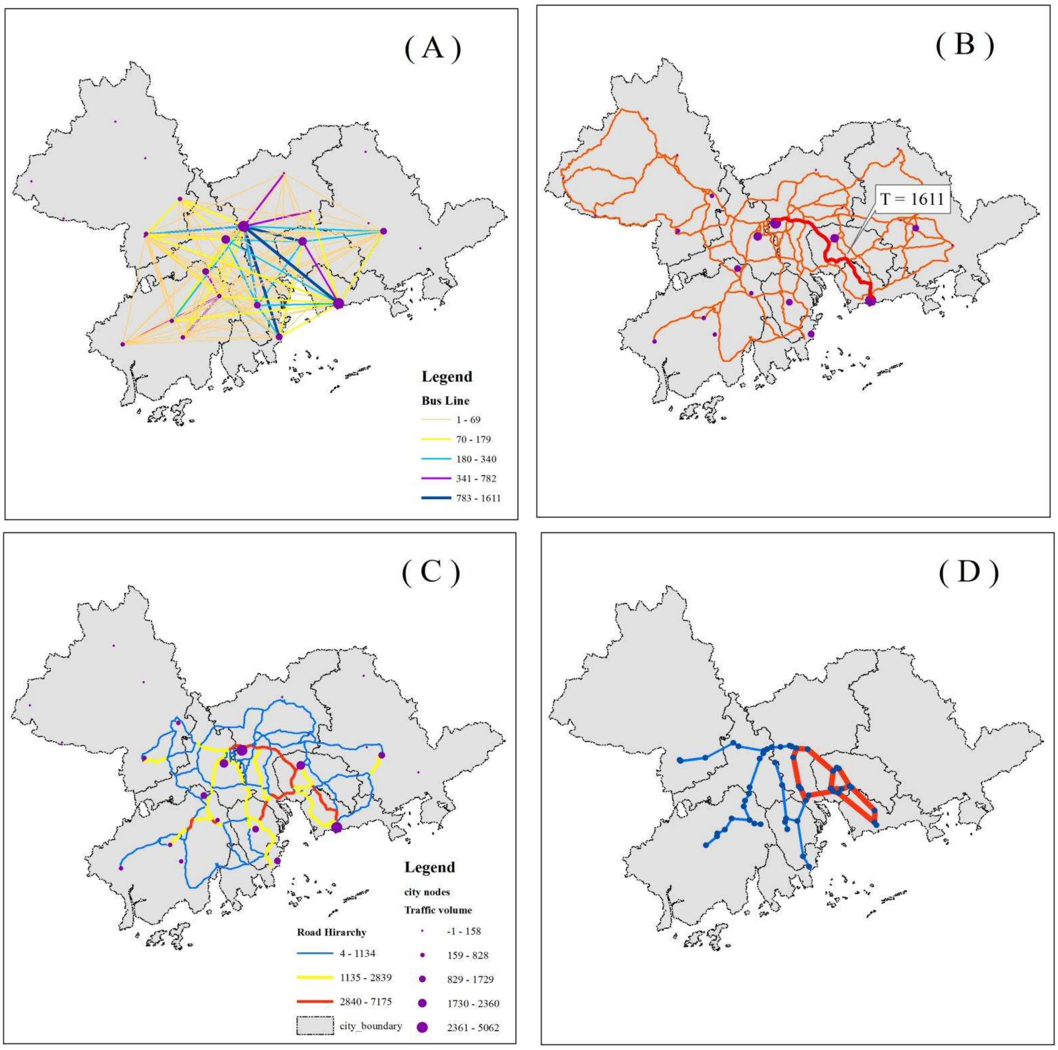
The method of traffic assignment was adopted here to extract the backbone of regional road network. The primary concern in traffic assignment models is route choice. The shortest path or the least cost path was set as the ideal path without considering traffic capacity or personal preference. This method is called the all or nothing traffic assignment, treating all users as homogenous agents who make route choices prior to departure based on some heuristic related to current traffic condition (Kurant, M. and P. Thiran, 2006).

In this paper, we choose the static traffic assignment method as the intercity interaction are mainly connected through express road, which are less influenced by traffic capacity or stochastic effects. Fig. 2 shows the general flow of the whole experiment with PRD（Pearl River Delta）as an example. (A) Shows the traffic flow between cities with straight line. The size of nodes is represented by the size of aggregated out-flow.

ring or a web is a more specific definition on circuit block (Xie, F. and D. Levinson, 2007). In this paper, we use the circuit to measure the backbone network.

$$\Phi_{circuit} = \frac{Total\ length\ of\ the\ backbone\ netwok\ on\ circuit}{Total\ length\ of\ the\ backbone\ netwok} \quad (1)$$

Figure 2: The four steps of analysis structure of the backbone for 23 urban regions, set PRD as an example.



(B) Shows the process of traffic assignment, as the traffic value would be assigned onto the shortest lines here. (C) Shows the hierarchy structure of road segment, which is classified into three classes based on nature breaks. (D) Shows the network graph after transforming the ‘backbone’ roads into nodes and linkages.

To identify the structure of the backbone structure of the main road networks, we defined the two graph indexes:

(1) Circuit: The connection and arrangement of backbone network can be abstracted as an undirected planar graph G = {E, V} where V is a collection of nodes (vertices) connected by directional links (edges) E. A

(2) Degree: The degree index is one of the most frequently used index to measure the importance of nodes. It is calculated as the total number of node j who connected the nodes i, specialized as a_{ij}, just as equation (2) shows.

$$K_i = \sum_{j \in G} a_{ij} \quad (2)$$

The standard deviation of all nodes' σ(**G**(k)) degree was calculated here to distinguish the second stage with the other two. As the core city forms an aggregated effect, the degree of the central nodes shows a distinct different here. As we can.

$$\sigma(\mathbf{G}(k)) = \sqrt{\frac{\sum_{i\in G}\ (K_i-\bar{K}_i)^2}{N}} \quad (3)$$

4 Results and conclusions

The results of the indexes showed as Table 2.

According to the experiment, if a backbone has more than 20 percentage circuit blocks, it could be called circular structure; for others, if the σ(k) value is larger than 0.9, the urban region are more like form a radiate structure; the rest urban regions are following the linear structure.

Based on the graph indexes as circuit and node degree, the spatial structure was identified into three different categories,

Table 2 The spatial index of 23 URs

metro	circuit	σ(k)	metro	circuit	σ(k)
YRD	0.64	0.93	LDP	0.05	1.10
NJX	0.58	0.68	CHC	0.00	0.93
CGZ	0.43	0.64	EHN	0.00	0.80
SGX	0.42	0.43	CYN	0.00	0.49
PRD	0.42	0.83	GZP	0.00	0.00
NNX	0.39	0.64	CIM	0.00	0.00
EHB	0.38	0.79	EFJ	0.00	0.80
HAC	0.33	1.60	JJY	0.00	0.50
BTH	0.26	0.98	CSX	0.00	0.47
SDP	0.22	0.69	LAX	0.00	0.98
CAH	0.12	1.66	CPL	0.00	1.55
TSM	0.09	0.67			

which are network structure, radial structure and linear structure (Fig.3 to Fig.5)

There are two major factors defining the spatial structure of urban regions: the economic develop level and geographic terrain. Higher economic development level will lead to a higher shape index as the economic activity shows more complexity. From the geographical perspective, urban regions along the coastline are more tend to form a linear structure.

Reference

Jiang B., Yin J., Zhao S. (2009), Characterizing the human mobility pattern in a large street network [J]. Physical Review E Statistical Nonlinear & Soft Matter Physics, 2009, 80(1): 21-36.

Fang, C., et al. (2010). Principles and Practices for the Sustainable Development of Chinese Urban Regions, Science Press, Beijing.[in Chinese].

Guo, L. and X. Cai (2008). Degree and weighted properties of the directed China railway network. International Journal of Modern Physics C 19(12): 1909-1918.

Xie, F. and D. Levinson (2007). Measuring the structure of road networks. Geographical Analysis 39(3): 336-356.

Zhang, W., et al. (2017). The backbone of urban street networks: Degree distribution and connectivity characteristics. Advances in Mechanical Engineering 9(11): 16878140-17742570.

Kurant, M. and P. Thiran (2006). Layered complex networks. Physical review letters, 96(13): 138701.

Figure 3: Examples for the circular structure of urban agglomerations

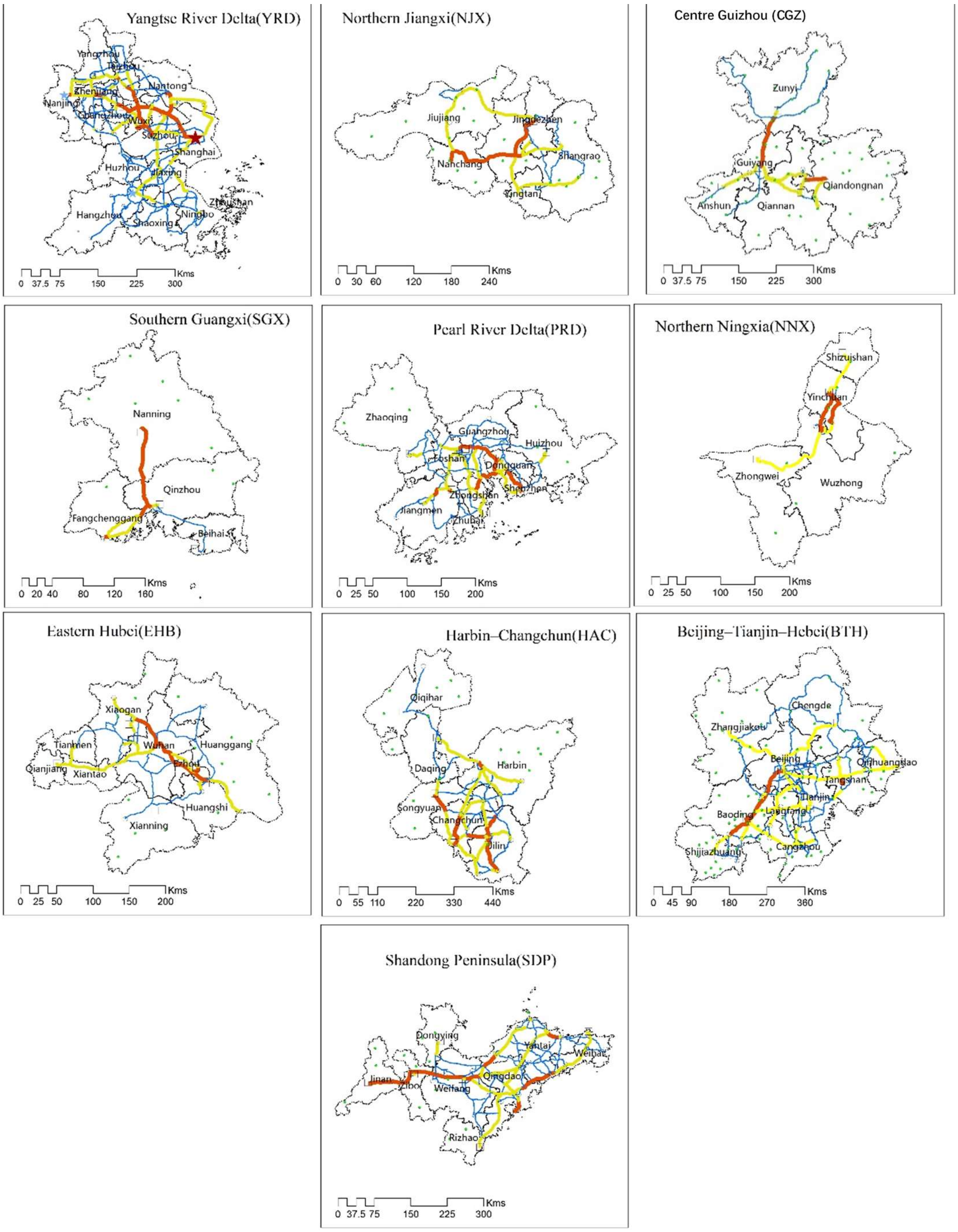


Figure 4: Examples for the radial structure of urban agglomerations

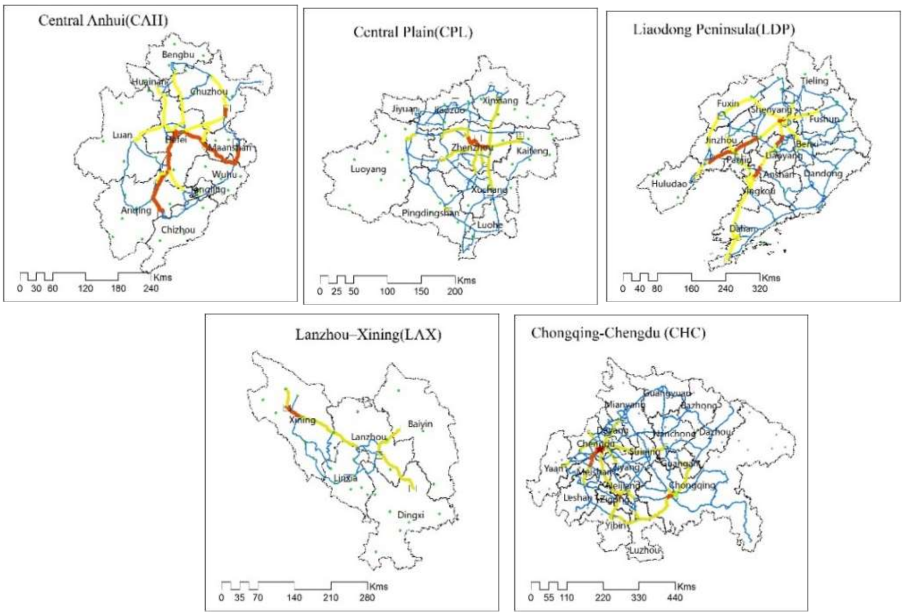


Figure 5: Examples for the linear structure of urban agglomerations